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ORIGINAL ARTICLE

How to minimize central line–associated bloodstream infections in a neonatal intensive care unit: a quality improvement intervention based on a retrospective analysis and the adoption of an evidence-based bundle

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Abstract

Central line–associated bloodstream infection (CLABSI) is a significant cause of morbidity and mortality in neonatal intensive care units (NICUs). A "bundle" is defined as a combination of evidence-based interventions that provided they are followed collectively and reliably, are proven to improve patient outcomes. The aim of this quasi-experimental study was to assess the impact of new central line insertion, dressing, and maintenance "bundles" on the rate of CLABSI and catheter-related complications. We performed a quality improvement (QI), prospective, before-after study. In the first 9-month period, the old "bundles" and pre-existing materials were used/applied. An intervention period then occurred with changes made to materials used and the implementation of new "bundles" related to various aspects of central lines care. A second 6-month period was then assessed and the CLABSI rates were measured in the NICU pre- and post-intervention period. The QI measures were the rate of CLABSI and catheter-related complications. Data are still being collected after the study to verify sustainability. The implementation of the new "bundles" and the change of certain materials resulted in a significantly decreased rate of CLABSI (8.4 to 1.8 infections per 1000 central venous catheter (CVC) days, $p = 0.02$,) as well as decreased catheter-related complications (47 to 10, $p < 0.007$).

Conclusions: The analysis of pre-existing "bundles" and the implementation of updated central line "bundles" based on best practice recommendations are crucial for reducing the rate of CLABSI in the NICU. The implementation of the new evidence-based central line "bundles" was associated with a significant reduction in CLABSI rate in our unit soon after implementation.

What is Known:
- *Central line–associated bloodstream infection (CLABSI) is a major cause of morbidity and mortality in the neonatal population.*
- *The implementation of evidence-based "bundles" in the NICU is associated with a reduction in the incidence of CLABSI.*

What is New:
- *For the improvement in quality care in the NICU, audits are necessary to assess the existing systems.*
- *The "Plan-Do-Study-Act cycle" is an effective tool to use when tackling challenges in an existing system. Using this tool assisted in the approach to reducing CLABSI in our NICU.*

Keywords Central venous catheter · CLABSI · CRBSI · Bloodstream infection · NICU · Neonate

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Abbreviations

CVC	Central venous catheter
CLABSI	Central line–associated bloodstream infection
CRBSI	Catheter-related bloodstream infection
NICU	Neonatal intensive care unit
VLBW	Very low birth weight
ELBW	Extremely low birth weight
QI	Quality improvement
UVC	Umbilical venous catheter
CICC	Centrally inserted central venous catheter
ECCs	Epicutaneo-cava catheters
CDC	Centers for Disease Control and Prevention

Introduction

Newborns admitted to neonatal intensive care units (NICUs) often require the placement of central venous catheters (CVCs) for the administration of drugs, fluids, and parenteral nutrition as well as for central venous monitoring. Despite the numerous advantages of CVCs, they can on the contrary be associated with the occurrence of infections and other complications.

A central line–associated bloodstream infection (CLABSI) is defined as a laboratory-confirmed bloodstream infection, not related to an infection from another site, that develops 48 h after the placement of a central line or within 48 h of its removal [1].

It is well documented that CLABSI is a major cause of morbidity and mortality in the neonatal intensive care unit (NICU) population. This is due to the high susceptibility of preterm newborns to nosocomial infections and sepsis given their poor skin integrity, need for invasive procedures, immature immune systems, and prolonged hospitalization [2]. Adams-Chapman et al. postulated that exposure of the preterm brain to inflammatory mediators during infectious episodes contributes to brain injury and poor developmental outcome [3]. Other studies have also demonstrated that in preterm infants who survive postnatal sepsis and necrotizing enterocolitis, neurodevelopmental and growth impairment is increased compared to their uninfected counterparts [4, 5]. The costs of hospitalization and duration of NICU stay also significantly increase with CLABSI [2, 6, 7]. Nevertheless, obtaining secure and reliable vascular access is necessary, as central lines are vital for the survival of these fragile infants. It is therefore of utmost importance to maximize the CLABSI reduction rate, continually aiming for no catheter-associated infections: "target zero."

A proven way of reducing CLABSI is through the use of "bundles" in the insertion and management of central lines. A "bundle" is defined as a combination of evidence-based interventions that have been shown to improve patient outcomes, provided they are adhered to correctly and reliably [8]. In a meta-analysis of 24 studies conducted by Payne et al. [2], a mean reduction rate of 60% in CLABSIs occurred following the introduction of a "care bundle" in the NICU. It is crucial to reduce the rates of infection in the NICU in order to increase survival and decrease neurodevelopmental impairment of this vulnerable population.

At the start of this study, the rate of CLABSI in our NICU was 8.4 cases per 1000 central line days, which is high in comparison to most neonatal units registered in the Vermont-Oxford Network. Our study was performed in a high complexity-high volume referral unit. The rate of CLABSI may be therefore higher compared to other kinds of small community-based units. But our CLABSI rate remained high even after comparing our data with the unpublished rate of CLABSI (2–3.5/1000 central line days) from KUL/Gasthuisberg—the "sister" university hospital in Flanders, Belgium, that has a high complexity case mix. We therefore planned a study in our unit to update central line techniques and "bundles" in order to try and decrease this rate. In order to achieve a sustainable decrease in the CLABSI rate, it was necessary to assess the existing systems and develop a clear framework before implementing and testing the effect of the new "bundles."

Aims

The aim of the study was to assess the impact of new central line insertion, dressing, and maintenance "bundles" on the rate of CLABSI and on the rate of catheter-related complications.

Methods

This quality improvement, prospective, before-after study was performed in an academic, tertiary 24-bed NICU (Saint-Luc Academic Clinic, Brussels, Belgium). Nurses are usually assigned 2 intensive neonates per nurse. Neonates hospitalized are mostly inborn babies (vs. outborn), with either critical medical or surgical conditions.

We followed the "Plan-Do-Study-Act cycle" (Fig. 1) and assessed the existing/"old" central venous catheter "bundles" before developing and testing the new "bundles." These new "bundles" served as the quality improvement (QI) intervention in clinical practice.

The study period is as follows:

1. Group 1: Pre-intervention period: 9 months: 1 January 2019–30 September 2019.
2. Intervention: 3 months of quality improvement implementation:

   New CLABSI "bundles" implemented.

3. Group 2: Post-intervention period: 6 months: 1 January 2020–30 June 2020.

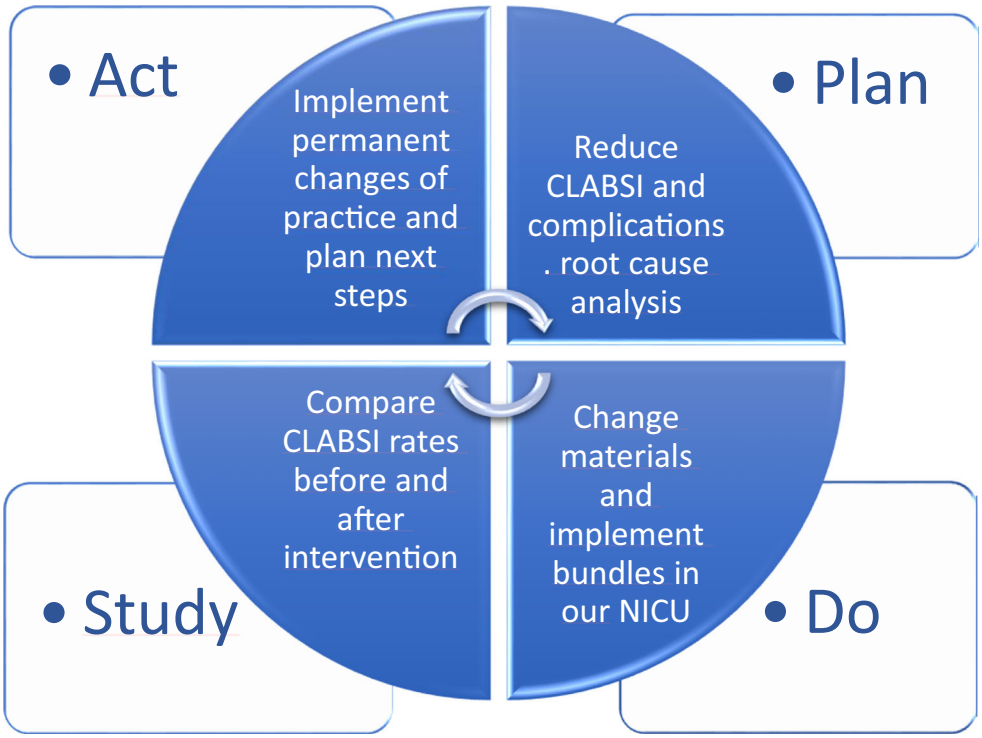

Fig. 1 Pathway of the quality improvement project according to the Plan-Do-Study-Act cycle

We chose to use the before-after approach to evaluate the effectiveness of the new "bundles" in our NICU. During this time frame, there were no changes in other protocols and local epidemiology.

Intervention

We performed an analysis of the previously existing clinical practices and "bundles" relating to central venous catheters. Following the 9-month observation study period and analysis, a "central line–dedicated team" consisting of one neonatologist, 5 nurses, and 2 members of the hospital hygiene team was created. This team was responsible for the implementation of updated catheter procedures as well as hosting monthly education sessions in the NICU.

The interventions included the change of certain materials, based on the latest international recommendations, and the update of the "bundles" related to central venous catheters [9].

The team focused on the following aspects:

1) Hand hygiene
2) Central line material and sterile dressing care
3) Drug preparation and administration
4) Prompt/timely catheter removal
5) Creation of an effective checklist
6) Specialized team

1) Hand hygiene

Nearly all preventive "bundles" focus on hand hygiene [10, 11]. In the meta-analysis performed by Ista et al. on critically ill patients of all ages [12], separate "bundles" were analyzed to establish the contributions of each "bundle" to CLABSI risk reduction. With respect to insertion "bundles," adding correct hand hygiene resulted in significant reduction in the CLABSI rate in adult ICUs. Several educational sessions involving all neonatal staff (nurses, assistants, supervisors, logistics, and paramedical staff) were held to highlight the importance of hand hygiene.

2) Central line material and sterile dressing care

Old-generation epicutaneo-cava catheters (used during the first period of the study) are made of silicone with two separate pieces connected before placement. These older generation catheters are now replaced by more resistant, single-piece polyurethane catheters.

Adjustments to the sterile dressing care in the new "bundle" included as follows: the line being fixed at the insertion point with a drop of cyanoacrylate glue and then covered with a transparent dressing (once the catheter tip position is radiologically confirmed). As the glue is transparent, the insertion point remains visible at all times. Central venous catheters were previously secured using sutures. This has been replaced by glue, Stat-lock®, and transparent dressings, keeping the insertion point easily visible at all times.

The umbilical venous catheter (UVC) fixation "bundle" was also modified. The catheters are now secured with sutures

and Steri-Strip® and then covered by a transparent sterile dressing.

The central line team created a sterile dressing care "bundle" and a checklist to ensure uniformity in practice, as well as performed several educational sessions to explain the new "bundle."

3) Drug preparation and administration

A new "bundle" regarding drug preparation and administration was created. Nurses are now required to wear sterile gloves and a mask when preparing any drug or infusion to be injected into a central line. To improve the disinfection of the hub during drug administration, we introduced the use of continuous passive disinfection caps impregnated with 70% isopropyl alcohol. The importance of allowing the port to dry before connecting the syringe was stressed.

4) Prompt/timely catheter removal

We highlighted strict criteria for prompt/timeous catheter removal, encouraging the removal of central lines as soon as enteral nutrition reached 120 ml/kg/day [13].

5) Creation of an effective checklist

The central line team designed central line insertion and maintenance checklists. These checklists included all the items essential for the correct execution of the "bundles," for example, the use of maximal barrier precautions when inserting central lines (sterile gloves, surgical face mask, sterile coat, use of 70% alcohol chlorhexidine in all patients with a birth weight > 1000 g, headgear, and extensive surgical draping of patient) [13–15]. The team was responsible to check if procedures were performed correctly and give feedback to those performing the procedure on the accuracy to which the "bundles" were adhered to.

6) Specialized team

Educational sessions regarding central line insertion and maintenance were held for all new residents and nurses by the specialized team.

The differences between the old bundles and the new bundles are listed in Table 3.

After the pre-intervention and intervention time periods, retrospective data was collected from the first group and prospective data collected from the second group of neonates fulfilling the inclusion criteria. Patient inclusion criteria included as follows: term and premature neonates, hospitalized in the NICU for more than 48 h, and a central line in place. Neonates with congenital heart diseases were excluded (as they are transferred and managed in the cardiac pediatric intensive care unit after surgery).

Measures

We chose the rate of CLABSI as the primary QI measure, and catheter-related complications, defined as thrombosis and rupture or dislocation of the catheter, as secondary QI measures. These secondary QI measures were chosen because the implementation of new materials and "bundles" should influence the occurrence of all central line complications, especially infection and dislocation. The decrease in the rate of infection is associated with the decrease in morbidity, mortality, and costs of hospitalization.

In the study, we focused on the incidence of CLABSI, not catheter-related bloodstream infection (CRBSI). We used the NEO-KISS [16] definition of CLABSI (Table, supplemental material) because the practice of obtaining two blood cultures following the growth of a skin commensal according to the 2008 Centers for Disease Control and Prevention (CDC) definition is challenging, particularly in the extremely low birth weight (ELBW) population [1].

For all patients meeting the inclusion criteria, we collected data of patient demographics and length of NICU stay. We collected the following data for each central line, even if multiple lines were placed in the same patient at various time points:

- Central line type: umbilical venous catheter (UVC) versus centrally inserted central venous catheter (CICC) versus epicutaneo-cava catheters (ECCs)
- Tip line position
- Number of central line days
- Occurrence of CLABSI and of other complications (dislocation, thrombosis, rupture of the catheter)

Statistical analysis

Catheters were the unit of measurement. Missing values were not imputed. Incidence rates per 1000 CVC days were calculated to test differences between the two groups, with comparisons over time.

Analysis was conducted using Microsoft Excel 2016 (Microsoft Inc., USA, 2016). The non-parametric statistical data and percent relative effect were calculated to investigate the sample data and potential difference in risk between the primary variables. A chi-square test was used to compare the 2 groups. A p value of < 0.05 was considered to be statistically significant.

Results

Analysis

The initial analysis showed that during the first time period, while most of updated international bundle recommendations on CVC insertion were followed and correctly applied, there was poor adherence to sterile dressing care and the maintenance "bundles."

During the study period, 430 neonates were included consecutively (Fig. 2).

Group 1 comprised the neonates enrolled from the pre-intervention time period and group 2 the neonates during the post-intervention period. Table 1 shows the demographic features of all the neonates included; there was no statistical difference between the 2 groups.

During the first study period, 241 neonates were enrolled. Among these patients, 140 (58%) required at least one central line. Forty percent of these neonates were very low birth weight (VLBW) infants. A total of 258 catheters were used in the 140 neonates and all of these catheters were analyzed, as many of the neonates had more than one catheter (up to 8 different catheters in the same patient). No CLABSI occurred in term infants.

In the second period, 189 neonates were enrolled. Among these, 113 (59.8%) required at least one central line and a total of 159 catheters were used. Thirty-eight percent of these newborns were very low birth weight (VLBW) infants. No CLABSI occurred in term infants. Table 2 summarizes the characteristics of the catheters in both groups.

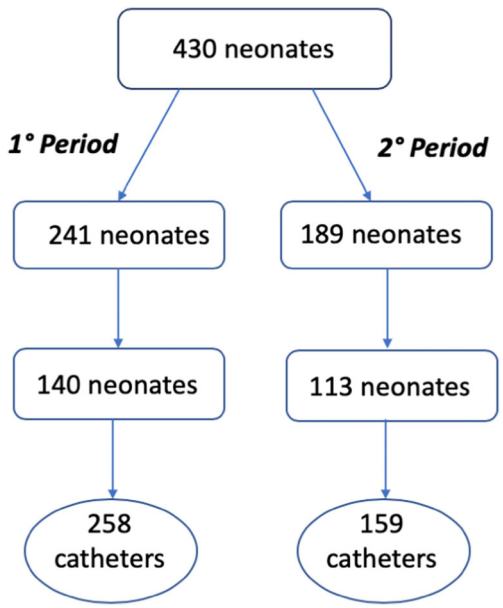

Fig. 2 Enrollment of the patients in the study: 430 neonates were enrolled. During the first study period, 241 neonates were enrolled. Among these patients, 140 required at least one central line and a total of 258 catheters were used. In the second period, 189 neonates were enrolled. Among these, 113 required at least one central line and a total of 159 catheters were used

The study included 2134 central line days of observation for period 1 and 1666 line days for period 2. During this first study period, 18 CLABSI occurred. The mean CLABSI rate, expressed as the number of cases per 1000 central line days, was 8.4 cases per 1000 central line days. Eighty-three percent of all CLABSI (15/18) were found among VLBW infants. When analyzing the data according to gestational age, 16/18 (88.9%) CLABSI occurred in neonates with a gestational age less than 32 weeks. Similarly to the study by Garcia et al., the most frequently isolated pathogens (66%) were coagulase-negative staphylococci [17] (*Staphylococcus epidermidis*, *Staphylococcus capitis*, and *Staphylococcus hominis*). One Gram-negative CLABSI (*Escherichia coli*) (6%) occurred. During the second period, 3 CLABSI occurred; the isolated pathogens were *S. epidermidis*, *S. capitis*, and *Citrobacter koseri*. One CLABSI occurred in an ELBW infant and 2 in neonates weighing more than 2500 g. The mean CLABSI rate was 1.8 cases per 1000 central line days. Sixty-six percent (2/3) of all CLABSI were found among VLBW infants. Thirty-three percent (1/3) of the CLABSI occurred in neonates with gestational age less than 32 weeks. There was a significant reduction of CLABSI ($p < 0.05$) during study period 2 versus study period 1. The relative risk of CLABSI calculated in comparing group 2 versus group 1 was 0.28 (95% CI 0.085–0.95). When analyzing the data of the neonates with a gestational age < 32 weeks, the relative risk of CLABSI comparing group 2 to group 1 was 0.08 (95% CI 0.01–0.6).

Regarding secondary outcomes, there was a significant reduction in the rate of catheter dislocation and technical issues, expressed as number of events (Table 2).

Discussion

The aim of the study was to assess the impact of new central line insertion, dressing, and maintenance "bundles" on the rate of CLABSI and on the rate of catheter-related complications in our NICU. This is crucial as CLABSI, responsible for much of the late-onset sepsis seen in NICUs, may significantly affect neonatal neurodevelopment and mortality [3–5]. Almost all VLBW neonates require central lines for their survival, and even neonates with higher birth weights and with complex medical or surgical conditions require central lines in the long term. Considering the high number of VLBW infants and high rate of infants with surgical conditions in our NICU, an improved management of central lines was essential to improve morbidity and mortality.

An important result of the study is that the analysis performed during the first period of the study allowed us to systematically identify which practices differed from international guidelines and were likely contributing to the increased rate

Table 1 Demographics of neonates with a catheter

Infant demographics	Group 1 total ($n = 140$)	Group 2 total ($n = 113$)	p value
Gestational age (week), mean (min–max)	33 (24–40)	32.7 (23–40)	0.47
Birth weight (g), mean (min–max)	1921 (600–4750)	2244 (410–4480)	0.26
Neonates with GA < 32 weeks, *n* (%)	51 (36.4)	49 (43.3)	0.46
Birth weight (g), *n* (%)			
≤ 750	13 (9.2)	12 (10.6)	0.14
751–1000	13 (9.2)	9 (8)	0.47
1001–1500	31 (22.1)	22 (19.4)	0.34
1501–2500	33 (23.6)	43 (38)	0.27
> 2500	50 (35.7)	27 (23.9)	0.70

of infection. This led to focused evidence-based new "bundles" being implemented and updated educational seminars with the aim to change the current practices.

Regarding *hand hygiene*, several educational sessions involving all neonatal staff were held and analysis on hand hygiene compliance was performed before and after the sessions, showing an increase in compliance after the campaign (Fig. 3).

Catheter materials changed from the old-generation ECCs to the new-generation polyurethane catheters, and we observed a decline in the rate of technical issues. As showed in Table 3, 13% of the old-generation catheters needed to be replaced due to technical issues, especially mechanical and malposition/migration problems. Our percentage of technical issues was similar to those reported in the Neonatal PICC1 Survey of peripherally inserted central catheter (PICC) practices performed in 2017 in Michigan in the USA [18].

Previously catheters were covered by Strips® and an opaque/non-transparent *dressing* preventing/obscuring the visibility of the insertion point (Fig. 4a). Dressings were modified in the new bundles (Fig. 4b). There were initial concerns of suspected interactions regarding the use of cyanoacrylate

Table 2 Catheter characteristics and complications. Catheter characteristics: no significant differences were found comparing the catheter type and the exit site between the two groups. Complications: there was a significant decrease in the number of CLABSI, of mechanical complications, and of dislocation

Catheter characteristics	Group 1 total ($n = 258$)	Group 2 total ($n = 159$)	p value	RR (95% CI)
Catheter type, number (%)				
ECC	128 (49.7%)	68 (42.7%)	0.17	
UVC	93 (36%)	58 (36.4%)	0.92	
CICC	37 (14.3%)	33 (20.7%)	0.08	
Exit site, number (%)				
Upper/lower limb	127 (49.2%)	68 (42.7%)	0.20	
Scalp	1 (0.4%)	1(0.6%)	0.72	
Neck	14 (5.4%)	12 (7.4%)	0.38	
Supra-clavicular	23 (9%)	20 (12.5%)	0.23	
Umbilical	93 (36%)	58 (36.4%)	0.92	
Infra-clavicular	1 (0.4%)	1(0.6%)	0.72	
Complications, number (%)				
None	212 (82%)	149 (93.7%)		
CLABSI total	18	3	*0.04*	0.28 (0.085–0.95)
CLABSI < 32 weeks	16	1	*0.01*	0.08 (0.01–0.6)
Mechanical (broken, occluded, disconnected)	13 (5%)	1(0.6%)	*0.015*	
Local concerns (erythema, phlebitis, extravasation)	8 (3%)	4 (2.5%)	0.73	
Unintentional dislocation/migration	21 (8%)	3 (1.9%)	*0.007*	
Other (pleural effusion, arrhythmia, deep venous thrombosis)	4 (2%)	2 (1.2%)	0.80	

RR relative risk (95% confidence interval)

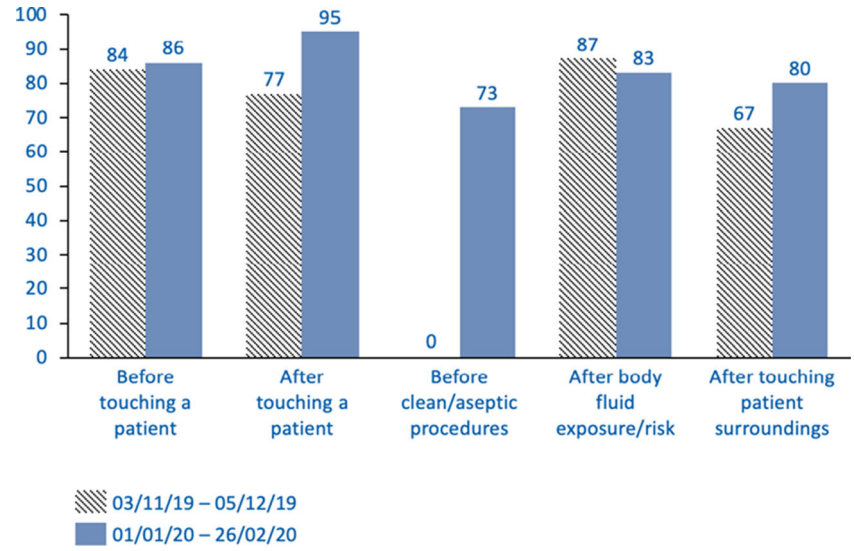

Fig. 3 Results of the campaign on hand hygiene: the item "before aseptic procedures" was not evaluated before the campaign

glue on the catheter's material itself, but Di Puccio et al. demonstrated that the long-term use of cyanoacrylate glue on polyurethane PICCs was not associated with any catheter damage [19]. Furthermore, Barone et al. were able to significantly reduce accidental dislodgement from 35 to 20% after introducing the routine use of glue in PICC fixation, proving its efficacy in securing central venous access [20]. Glue has also shown immediate hemostatic properties, thus reducing the need to redo sterile dressings due to bleeding and reducing the manipulations of lines [21, 22]. By "sealing" the entry site of the catheter and reducing bacterial translocation, glue also assists in reducing the risk of extra-luminal contamination, adding antimicrobial properties to its benefits [23]. Scoppettuolo et al. speculate that glue also has an antithrombotic property by reducing the "in and out" movement of the catheter at the entry site preventing and reducing local damage to the endothelium of the vein [22].

CICCs were previously secured with sutures (Fig. 5a). As evident in Fig. 5b, sutures were replaced by glue, Stat-lock®, and a transparent dressing ensuring constant visibility of the insertion point. Previously the umbilical catheters were secured using sutures and fixed with a tape "bridge," leaving the umbilical cord uncovered (Fig. 6a). After the implementation period, the umbilical catheters were covered with the new dressing to reduce the risk of contamination (Fig. 6b).

Previously the nurses wore a gown, a mask, and sterile gloves only when preparing perfusions and connecting parenteral nutrition. All other *drug preparation and administration* medications were prepared without sterile extra precautions. With the implementation of the new "bundle," the nurses were required to wear sterile gloves and a mask when preparing any drug or infusion to be injected into a central line.

Concerning drug administration, another important issue identified was the disinfection of the hub (entry point to the

Table 3 Differences between the old bundles and the new bundles that were introduced in the second period of the study

	Old "bundle"	New "bundle"
Hand hygiene		Increased educational sessions to enhance adherence to correct hand hygiene
Central line material and dressing care	Old-generation 2-piece epicutaneo-cava catheters (silicone) Non-transparent dressing "Bridge" for UVC Sutures for CICC, non-transparent dressing	New single-piece polyurethane catheters Cyanoacrylate glue Occlusive transparent dressing Sterile transparent dressing Stat-lock, glue, and transparent dressing
Drug preparation and administration	No sterile preparation of drugs No disinfection caps	Sterile gloves and masks obligatory Disinfection caps
Prompt timely catheter removal	Catheter removed when enteral feeds reached 140–150 ml/kg/day	Catheter removed when enteral feeds reached 120 ml/kg/day
Creation of an effective checklist	No checklists available	Checklists created
Specialized team	No dedicated team	Dedicated team Educational sessions

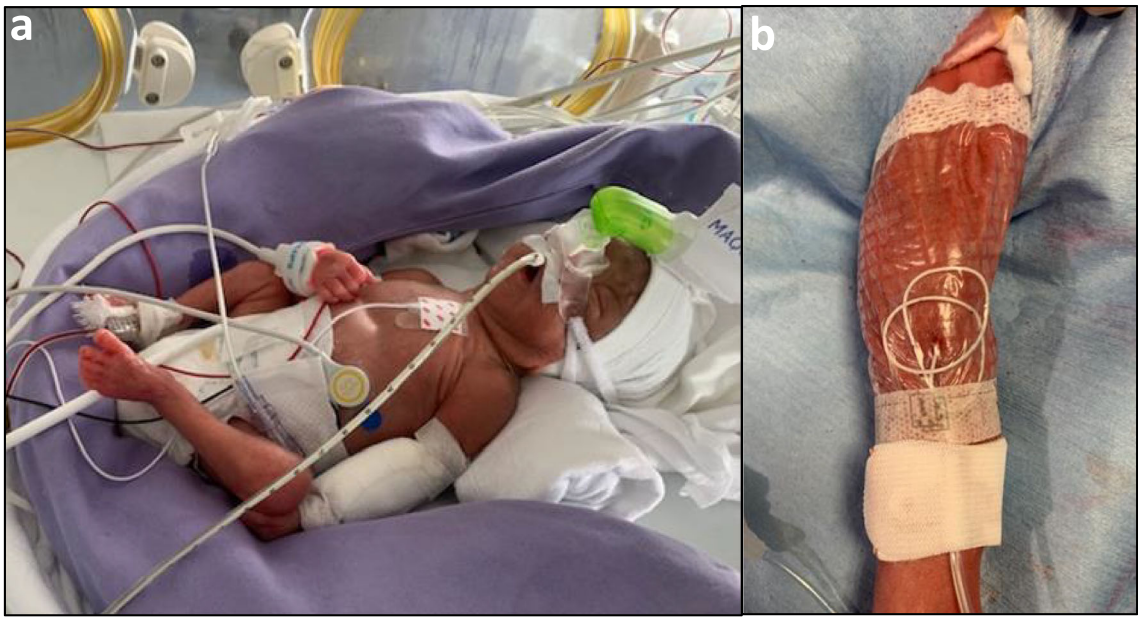

Fig. 4 Previous (**a**) and present (**b**) dressing of ECCs. Catheters previously were covered by Strips® and an opaque/non-transparent dressing preventing/obscuring the visibility of the insertion point (**a**). Dressings have been modified to allow inspection of the exit site at all times: the line is fixed at the insertion point with a drop of cyanoacrylate glue and then covered with a transparent dressing. As the glue is transparent, the insertion point remains visible (**b**)

central line). It is well known that microorganisms can gain access to the central line through the hub subsequently disseminating into the bloodstream, causing bloodstream infections [24]. Bundles recommend scrubbing the hub with 70% alcohol chlorhexidine for at least 15 s [25, 26] and then allowing the hub to dry before connecting the syringe. We introduced the use of continuous passive disinfection caps impregnated with 70% isopropyl alcohol (Fig. 7) to

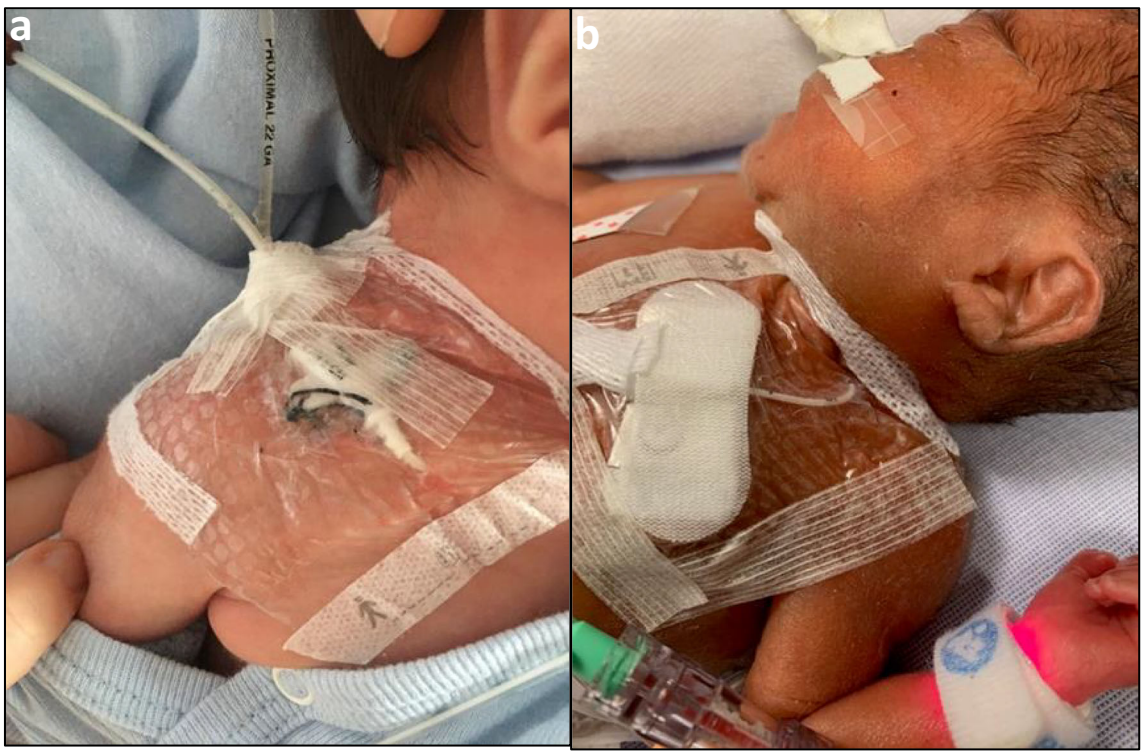

Fig. 5 Previous (**a**) and present (**b**) dressing of CICCs. Previously catheters used to be fixed with sutures (**a**). These were replaced by the use of glue, Stat-lock®, and transparent dressings, keeping the insertion point easily visible at all times (**b**)

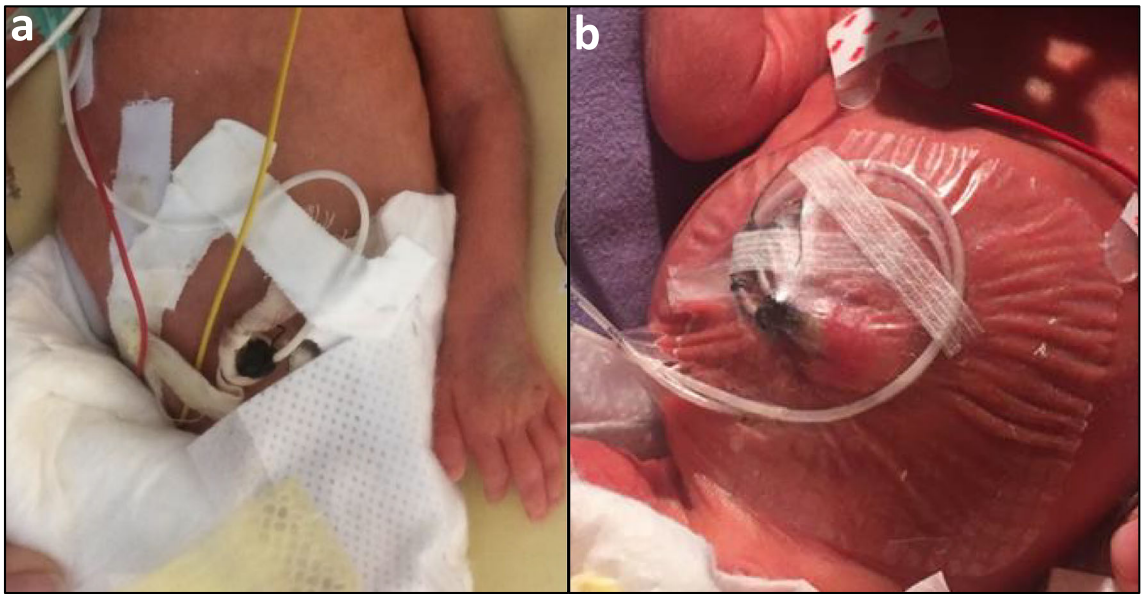

Fig. 6 Previous (**a**) and present (**b**) dressing of UVCs. Previously the umbilical catheters were secured using sutures and fixed with a tape "bridge," leaving the umbilical cord uncovered (**a**). The catheters are now secured with sutures and Steri-Strip® and then covered by a transparent sterile dressing to reduce the risk of contamination (**b**)

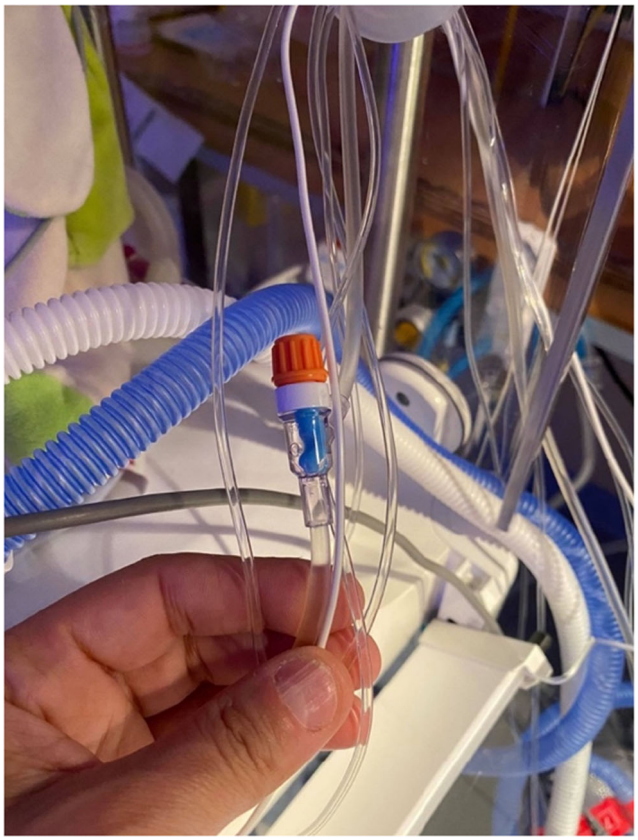

Fig. 7 Passive disinfection caps. We introduced the use of continuous passive disinfection caps impregnated with 70% isopropyl alcohol (Curos®) to decontaminate the injection port, thereby reducing colonization of central catheters

decontaminate the injection port, thereby reducing colonization of central catheters [27]. A recent study comparing standard cleaning to continuous passive disinfection caps for the decontamination of needle-free connecters showed a significant reduction in *Staphylococcus aureus* contamination of the injection ports when the disinfection caps were used, leading to a lower rate of CLABSI [28].

Length of catheter duration and time of catheter removal were also key points of focus as many studies have suggested that the longer the catheter remains in place, the greater the risk of catheter complications, including CLABSI [29, 30].We chose the time point of central line removal as soon as enteral nutrition reached 120 ml/kg/day. Erdei et al. [31] changed their feeding protocol, by discontinuing parenteral nutrition and removing the central line when an enteral feeding volume of 100 ml/kg/day was reached. This reduced the number of central line days and significantly reduced the rate of CLABSI.

In 2011, a prospective cohort study conducted by Schulman et al., involving 18 NICUs in the USA, demonstrated that the use of maintenance checklists reduced CLABSIs from 3.5 to 2.1 per 1000 central line days [32].

To establish continuous quality improvement, it is important to follow a model such as the "Plan-Do-Study-Act cycle" which provides framework for developing, testing, and implementing changes leading to improvement. The central line team designed updated *checklists* to ensure that procedures were performed correctly. These checklists highlighted the areas that required further attention.

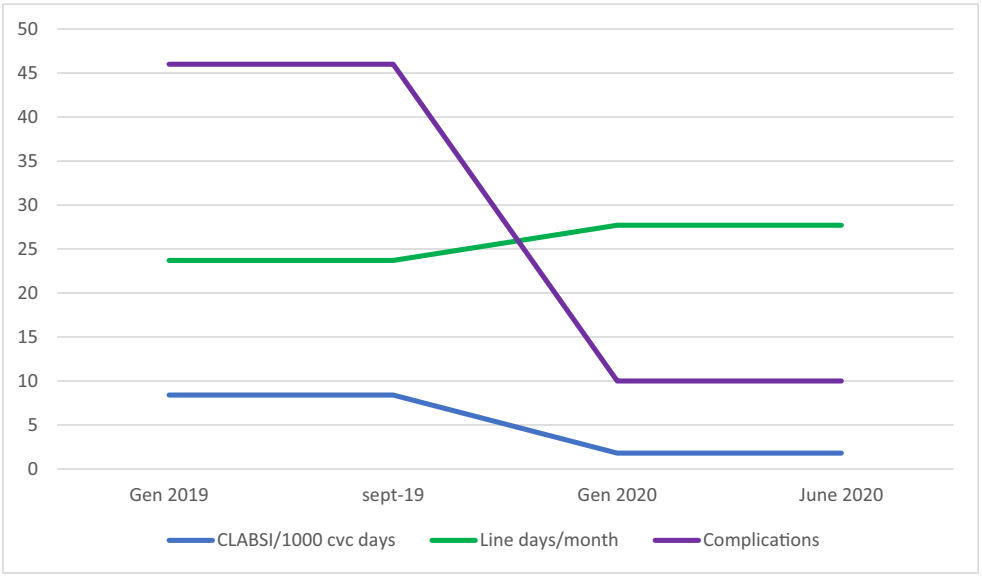

Fig. 8 Graph showing the reduction of catheter-related complications during the 2 study periods. Despite an increase in the duration of catheter days, there was a decrease in the number of CLABSI and other catheter-related complications from period 1 to period 2

As our hospital is an academic institution with many undergraduate and post-graduate clinical students and assistants, it was not possible to have a *dedicated specialized team* inserting all the central lines. Nevertheless, educational sessions regarding central line insertion are held for all residents and nurses on entering the NICU.

Our results showed not only a reduction in CLABSI but also a reduction in other catheter-related complications as well (Fig. 8). In particular, there was a major reduction of accidental dislocation of the lines, likely related to the introduction of the single-piece lines, glue, and the suture-less devices. Our results showed a reduction in the rate of CLABSI, despite an increase in the number of catheter days per infant. This increased number of catheter days per infant may reflect a greater case mix severity or be the consequence of a better catheter management. The number needed to treat (NNT) to prevent a CLABSI with the intervention was 21.4 overall in all gestational ages. Most encouraging was the low NNT of 4.5 in the group with a gestational age < 32 weeks.

The initial implementation period of the new central line "bundles" was characterized by poor compliance rate by the nursing team, thought to be primarily due to most of the senior nursing staff being resistant to change. Nevertheless, after performing educational seminars and giving clear explanations on the changing "bundles," the staff were more willing to adopt the new procedures. Having a dedicated team of nurses within the unit "pioneering" the new procedures facilitated the acceptance of the procedures, as the change came from the existing nursing team and was not imposed by an outsider. Regarding the medical staff, it was easier to introduce the changes after the first educational seminars were performed.

The first results of the hand hygiene campaign suggested that while there was an improvement in compliance, there remain areas for improvement. Further audits and feedback seminars are necessary to reach 100% compliance.

A limitation of this study was the retrospective data collection for the pre-intervention cohort (for pragmatic purposes) and the limited number of patients due to the single-center design. The prospective, post-interventional group will serve as the new baseline to which further cohorts can be compared. Ongoing evaluation and continued updates are necessary. Future "bundles" will include a more aggressive feeding approach with the aim to reduce catheter days per infant as well as the creation of a specialized nursing team to handle the dressings and general management of central lines. This nursing team created will ensure that a specialized nurse is present in the NICU at every shift. Further interventions on safer drug administration are planned to further reduce the rate of CLABSI and strengthen the goal of reaching zero infections. The interventions validated in this study will be tested in other intensive care units in order to determine whether they are unit specific or can be generalized on a broader basis.

Conclusion

The analysis of the central line insertion and maintenance procedures/"bundles," previously in place in the NICU, was essential to identify crucial aspects differing from international recommendations. This led to the modification and improvement of the procedure "bundles" and ensured a standard parallel to the most updated guidelines. One of the most important factors in increasing the effectiveness of these interventions is continued routine audits and analyses, identifying the techniques and procedures most associated with the increased incidence of CLABSI. The identified techniques or procedures can then be modified by drafting new "bundles"

and educating staff in educational feedback sessions to ensure that the new techniques and procedures are clearly communicated, understood, accepted, and effectively applied.

Authors' contributions SB and FP designed and wrote the article.
KC collected the data.
OD revised the manuscript for intellectual content.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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